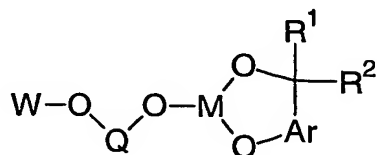


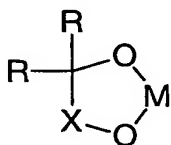
## WHAT IS CLAIMED IS:

1. A bis-chelating ligand composition having the generic formula:

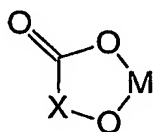


- 5 wherein M is a Group VB element selected from phosphorus (P), arsenic (As), or antimony (Sb);  $R^1$  and  $R^2$  are each independently selected from hydrogen and monovalent hydrocarbyl radicals; or alternatively,  $R^1$  and  $R^2$  are bonded together to form a hydrocarbyl or substituted hydrocarbyl diradical that taken with the methylene carbon of formula I forms a cyclic or heterocyclic ring; or alternatively, one of  $R^1$  or  $R^2$  is hydrogen or a monovalent hydrocarbyl radical, while the other of  $R^1$  or  $R^2$  is a hydrocarbyl or substituted hydrocarbyl radical  
10 bonded to an atom in the aryl group Ar to form a cyclic or heterocyclic ring; Ar is selected from 1,2-arylenes; Q is selected from the group consisting of 1,2-arylenes, 2,2'-bisarylenes and alkyl diradicals; and W is selected from the group consisting of Group VB element-containing formulas II, III, IV, and V:

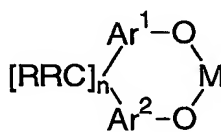
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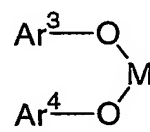
(II)



(III)



(IV)



(V)

- wherein M is as defined hereinbefore; each R is independently selected from monovalent hydrocarbyl radicals; X is selected from alkyl and aryl diradicals;  $Ar^1$  and  $Ar^2$  are each  
20 independently selected from 1,2-arylenes;  $Ar^3$  and  $Ar^4$  are each independently selected from monovalent aryl radicals; and n in formula IV is 0 or 1.

2. The composition of Claim 1 wherein each M is phosphorus (P).  
3. The composition of Claim 1 wherein each  $R^1$  and  $R^2$  is selected from hydrogen,  $C_{1-20}$  primary alkyl radicals, and substituted  $C_{1-20}$  primary alkyl radicals.  
25 4. The composition of Claim 1 wherein  $R^1$  and  $R^2$  are bonded together to form a diradical that taken with the methylene carbon of formula I forms a  $C_{3-8}$  cyclic or heterocyclic ring.

5. The composition of Claim 1 wherein Ar is a C<sub>6-20</sub> 1,2-arylene or a substituted derivative thereof.

6. The composition of Claim 5 wherein Ar is selected from the group consisting of 1,2-phenylene, 1,2-naphthylene, and 2,3-naphthylene, 3-methyl-1,2-phenylene, 3-ethyl-1,2-phenylene, isopropyl-1,2-phenylene, 3,5-dimethyl-1,2-phenylene, 3,5-diethyl-1,2-phenylene, 3,5-diisopropyl-1,2-phenylene, 3-methyl-1,2-naphthylene, and 1-methyl-2,3-naphthylene.

7. The composition of Claim 1 wherein Q is selected from the group consisting of C<sub>6-20</sub> 1,2-arylenes, C<sub>12-30</sub> 2,2'-bisarylenes, and C<sub>1-20</sub> alkyl diradicals, and substituted derivatives thereof.

8. The composition of Claim 1 wherein Q is selected from the group consisting of 2,2'-biphenyl, 3,3'-di-tert-butyl-2,2'-biphenyl, 3,3'-bis(trimethylsilyl)-5,5'-di-tert-butyl-2,2'-biphenyl, 3,3',5,5'-tetra-tert-butyl-2,2'-biphenyl, 3,3'-di-tert-butyl-5,5'-dimethoxy-2,2'-biphenyl, 3,3',5,5'-tetra-tert-amyl-2,2'-biphenyl, 3,3'-di-phenyl-5,5'-di-tert-butyl-2,2'-biphenyl, 3,3'-di-tert-butyl-5,5'-bis(trimethylsilyl)-2,2'-biphenyl, 3,3'-bis(trimethylsilyl)-5,5'-bis(2,4,6-trimethylphenyl)-2,2'-biphenyl, ethylene (-CH<sub>2</sub>CH<sub>2</sub>-), 1,3-propylene (-CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>-), 1,2-phenylene (-C<sub>6</sub>H<sub>4</sub>-), 1,2-naphthylene (-C<sub>10</sub>H<sub>6</sub>-), 2,3-naphthylene (-C<sub>10</sub>H<sub>6</sub>-), 3,5-dichloro-1,2-phenylene, 3,5-dibromo-1,2-phenylene, 3-iodo-5-methyl-1,2-phenylene, 3,5-diisopropyl-1,2-phenylene, 3,5,6-trichloro-1,2-phenylene, 3-phenyl-1,2-phenylene, 1,1-diethyl-1,1-methylene, 1,1-cyclohexylidene, 1,1-cycloheptylidene, and 3-isopropyl-6-methyl-1,2-phenylene.

9. The composition of Claim 1 wherein each R is independently selected from hydrogen and C<sub>1-20</sub> monovalent primary alkyl radicals.

10. The composition of Claim 1 wherein X is selected from the group consisting of C<sub>1-20</sub> alkyl diradicals, C<sub>6-20</sub> aryl diradicals, and substituted derivatives thereof.

11. The composition of Claim 1 wherein X is selected from the group consisting of methylene (-CH<sub>2</sub>-), ethylene (-CH<sub>2</sub>CH<sub>2</sub>-), 1,3-propylene (-CH<sub>2</sub>CH<sub>2</sub>CH<sub>2</sub>-), 1,2-phenylene (-C<sub>6</sub>H<sub>4</sub>-), 1,2-naphthylene (-C<sub>10</sub>H<sub>6</sub>-), 2,3-naphthylene (-C<sub>10</sub>H<sub>6</sub>-), 3,5-dichloro-1,2-phenylene, 3,5-dibromo-1,2-phenylene, 3-iodo-5-methyl-1,2-phenylene, 3,5-diisopropyl-1,2-phenylene, 3,5,6-trichloro-1,2-phenylene, 3-phenyl-1,2-phenylene, 1,1-diethyl-1,1-methylene, 1,1-cyclohexylidene, 1,1-cycloheptylidene, and 3-isopropyl-6-methyl-1,2-phenylene.

12. The composition of Claim 1 wherein  $\text{Ar}^1$  and  $\text{Ar}^2$  in formula IV are each independently selected from the group consisting of  $\text{C}_{6-20}$  1,2-arylenes and substituted derivatives thereof.

13. The composition of Claim 1 wherein  $\text{Ar}^1$  and  $\text{Ar}^2$  in formula IV are each independently selected from the group consisting of 1,2-phenylene, methyl-1,2-phenylene, ethyl-1,2-phenylene, isopropyl-1,2-phenylene, 5-tert-butyl-1,2-phenylene, dimethyl-1,2-phenylene, diethyl-1,2-phenylene, diisopropyl-1,2-phenylene, 3,5-di-tert-butyl-1,2-phenylene, 3-tert-butyl-5-methoxy-1,2-phenylene, 3-trimethylsilyl-5-tert-butyl-1,2-phenylene, 3,5-di-tert-amyl-1,2-phenylene, 3-trimethylsilyl-5-(2,4,6-trimethylphenyl)-1,2-phenylene, 3-phenyl-5-tert-butyl-1,2-phenylene, 1,2-naphthylene and substituted variations of 1,2-naphthylene.

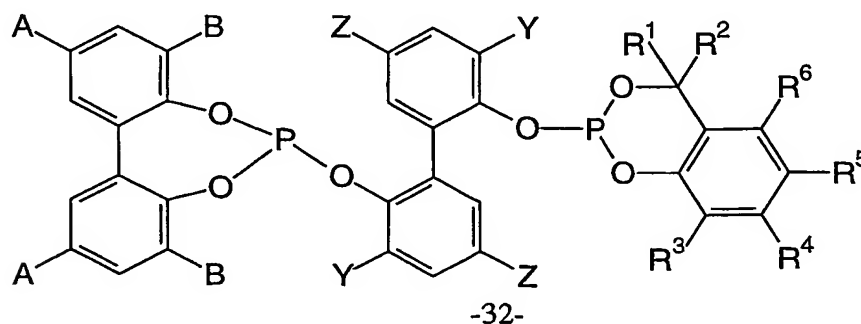
14. The composition of Claim 1 wherein  $\text{Ar}^3$  and  $\text{Ar}^4$  in formula V are each independently selected from the group consisting of  $\text{C}_{6-20}$  monovalent radicals and substituted derivatives thereof.

15. The composition of Claim 1 wherein  $\text{Ar}^3$  and  $\text{Ar}^4$  in formula V are each independently selected from the group consisting of phenyl, tolyl, xylyl, ethylphenyl, isopropylphenyl, 2-tert-butylphenyl, 2,4-dimethylphenyl, 2,4-diethylphenyl, 2,4-diisopropylphenyl, 2,4-di-tert-butylphenyl, 2,4-dimethoxyphenyl, 2,4-di-tert-amylphenyl, 2-tert-butyl-4-methoxyphenyl, 2-trimethylsilyl-4-tert-butylphenyl, and naphthyl.

16. The composition of Claim 1 wherein each M is phosphorus and Q is a 2,2'-bisarylene.

17. The composition of Claim 16 wherein each M is phosphorus; Q is a 2,2'-bisarylene; and W is Formula IV.

18. The composition of Claim 17 wherein each M is phosphorus; Q is a 2,2'-bisarylene; W is selected from formula IV; and n is 0, the composition being represented by the following formula:



wherein  $R^1$  and  $R^2$  are each independently selected from hydrogen and primary alkyl radicals, or wherein  $R^1$  and  $R^2$  are bonded together to form a diradical that together with the methylene carbon of formula I forms a cyclic or heterocyclic ring;  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$ , A and Z are each independently selected from the group consisting of hydrogen, halogen, monovalent hydrocarbyl radicals, alkoxy radicals and tri(hydrocarbyl)silyl radicals; and B and Y are each independently selected from aryl radicals, tertiary alkyl radicals, and tri(hydrocarbyl)silyl radicals.

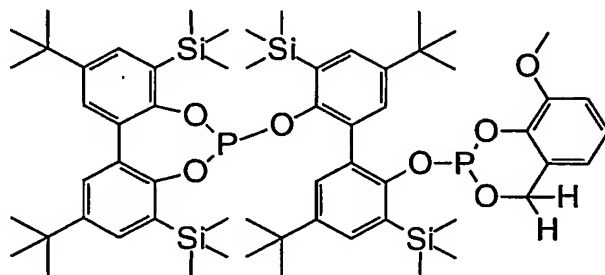
19. The composition of Claim 18 wherein each  $R^3$ ,  $R^4$ ,  $R^5$ ,  $R^6$ , A and Z is independently selected from the group consisting of hydrogen, halogen (more preferably, chloro, bromo, iodo), alkyl, aryl, alkaryl, aralkyl, alicyclic, alkoxy, aryloxy, hydrocarbyl carbonyl [ $-C(O)R^7$ ], hydrocarbyl carboxy [ $-OC(O)R^7$ ] (wherein  $R^7$  is a monovalent hydrocarbyl radical), and tri(hydrocarbyl)silyl radicals; the aforementioned organic, hydrocarbyl, and tri(hydrocarbyl)silyl radicals each comprising from 1 to about 20 carbon atoms.

20. The composition of Claim 18 wherein each A is independently selected from hydrogen, chloro, bromo, iodo, methyl, ethyl, tertiary butyl, isoamyl, tertiary amyl, tertiary octyl, methoxy, acetyl [ $CH_3C(O)-$ ], propionyl [ $CH_3CH_2C(O)-$ ] and trimethylacetoxyl [ $(CH_3)_3C-C(O)O-$ ] radicals; and each Z is independently selected from tertiary butyl, tertiary amyl, tertiary octyl, tri(methyl)silyl, tri(ethyl)silyl, xylyls, dimethylphenyls, diethylphenyls, trimethylphenyls, and trimethylacetoxyl radicals.

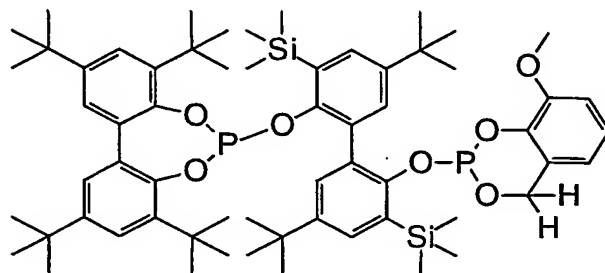
21. The composition of Claim 18 wherein B and Y are each independently selected from aryl radicals, tertiary alkyl radicals, and tri(hydrocarbyl)silyl radicals having from 3 to about 30 carbon atoms.

22. The composition of Claim 18 wherein each B is independently selected from tertiary butyl, trimethylsilyl, phenyl, dimethylphenyl, and trimethylphenyl radicals.

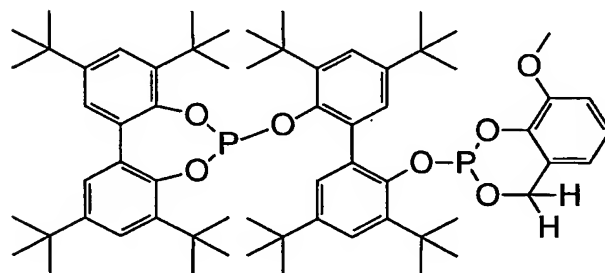
23. The composition of Claim 1 being selected from the following species:



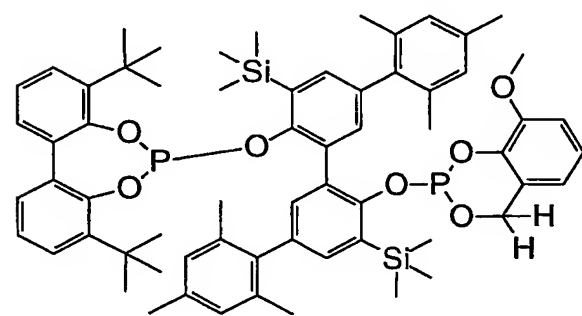
Ligand A



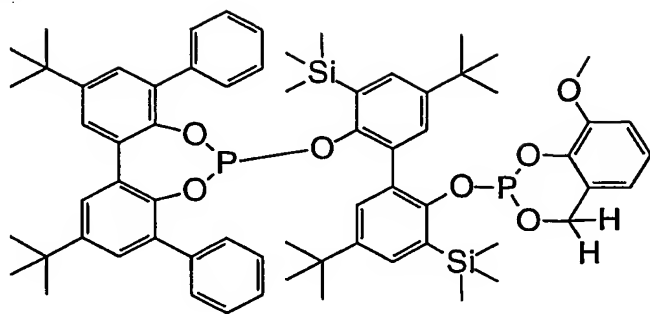
Ligand B



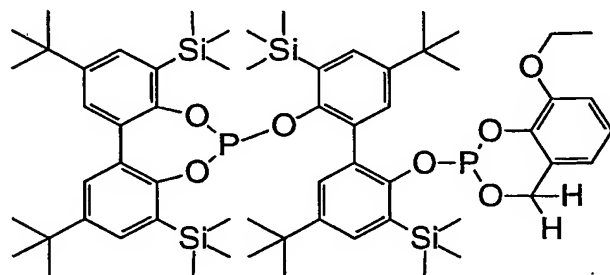
Ligand C



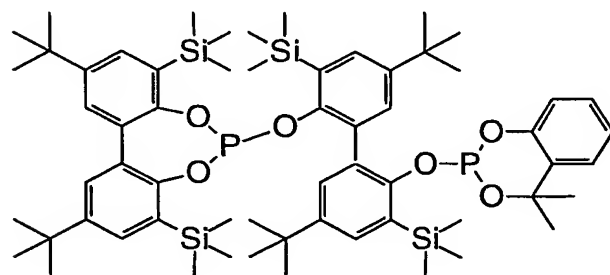
Ligand D



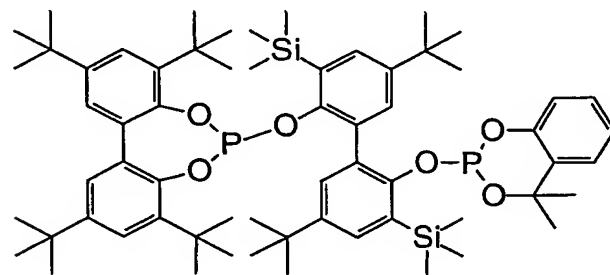
Ligand E



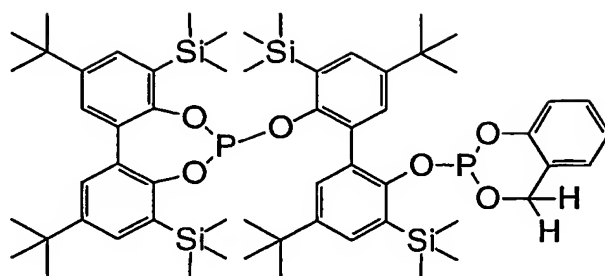
Ligand F



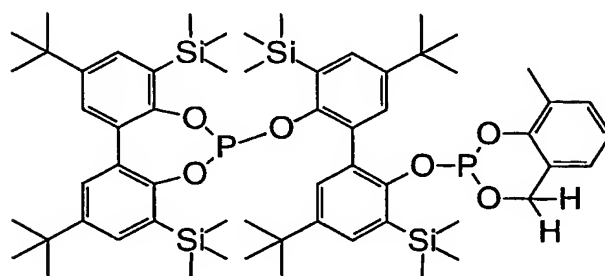
Ligand G



Ligand H



Ligand I



Ligand J

24. A transition metal complex catalyst or complex catalyst precursor comprising a Group VIII transition metal bonded to at least one molecule of ligand of Claim 1, optionally, further bonded to carbon monoxide, hydrogen, or both carbon monoxide and hydrogen.

25. The composition of Claim 24 wherein the Group VIII transition metal is selected from ruthenium, rhodium, cobalt, and iridium.

26. The composition of Claim 24 wherein the ligand is selected from the compositions of Claim 18.

27. A solution comprising an organic solvent, free ligand, and a transition metal complex catalyst or complex catalyst precursor composition comprising a Group VIII transition metal bonded to at least one molecule of ligand, wherein the bonded and optionally the free ligands have the formula of Claim 1.

28. The solution of Claim 27 wherein the Group VIII transition metal is selected from the group consisting of ruthenium, rhodium, cobalt, and iridium.

29. The solution of Claim 27 wherein the bonded and optionally the free ligands are independently selected from the group of ligands shown in Claim 18.

30. A carbonylation process comprising contacting an organic compound capable of being carbonylated with carbon monoxide in the presence of a transition metal complex catalyst comprising a Group VIII transition metal bonded to at least one molecule of ligand, optionally, in the presence of free ligand; wherein the bonded and optionally the free ligands have the formula shown in Claim 1, the contacting being conducted under carbonylation conditions sufficient to prepare the corresponding carbonylated organic compound.

31. The process of Claim 30 wherein the carbonylation comprises a simple carbonylation, hydroformylation, hydroacylation, hydrocyanation, hydroamidation, hydroesterification, or hydrocarboxylation.

32. The process of Claim 30 wherein the Group VIII transition metal is selected from ruthenium, rhodium, cobalt, and iridium.

33. The process of Claim 30 wherein the bonded and optionally free ligands are each independently selected from the ligands listed in Claim 18.

34. The process of Claim 30 comprising a hydroformylation process wherein an olefinically unsaturated aliphatic hydrocarbon is contacted with carbon monoxide in the presence of hydrogen.

35. The hydroformylation process of Claim 34 wherein the olefinically unsaturated aliphatic hydrocarbon contains from 2 to about 60 carbon atoms and one or more unsaturated groups.

36. The carbonylation process of Claim 34 wherein the olefinically unsaturated aliphatic hydrocarbon is selected from the group consisting of alpha olefins, internal olefins, alkyl alkenoates, alkenyl alkanoates, alkenyl alkyl ethers, and alkenols.

37. The carbonylation process of Claim 34 wherein the olefinically unsaturated aliphatic hydrocarbon is selected from the group consisting of ethylene, propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-decene, 1-dodecene, 1-octadecene, 2-butene, 2-methyl propene (isobutylene), isoamylene, 2-pentene, 2-hexene, 3-hexene, 2-heptene, cyclohexene, propylene dimers, propylene trimers, propylene tetramers, 2-ethylhexene, styrene, 3-phenyl-1-propene, butadiene, 1,3-cyclohexadiene, 1,4-cyclohexadiene, 1,7-octadiene, 3-cyclohexyl-1-butene, allyl alcohol, hex-1-en-4-ol, oct-1-ene-4-ol, vinyl acetate, allyl acetate, 3-butenyl acetate, vinyl propionate, 1-vinyl-3-cyclohexene, allyl propionate, allyl butyrate, methyl methacrylate,



3-butenyl acetate, vinyl ether, vinyl methyl ether, allyl ethyl ether, n-propyl-7-octenoate, methyl 1-decenoate, 3-butenenitrile, 5-hexenamide, methyl oleate, soybean oil and castor oil.

38. The carbonylation process of Claim 30 wherein the process is conducted in the presence of a solvent selected from the group consisting of saturated hydrocarbons, aromatic hydrocarbons, ethers, aldehydes, ketones, nitriles, and aldehyde condensation products.

39. The carbonylation process of Claim 30 wherein the process is conducted in the presence of free ligand having the formula in Claim 1.

40. The carbonylation process of Claim 30 wherein the molar ratio of ligand to Group VIII transition metal is greater than about 1.1/1 and less than about 100/1.

41. The carbonylation process of Claim 30 wherein the carbonylation process temperature is greater than about 30°C and less than about 200°C.

42. The carbonylation process of Claim 30 wherein the carbonylation process total pressure is greater than about 1 psia (7 kPa) and less than about 10,000 psia (68,948 kPa).

43. The carbonylation process of Claim 30 wherein the carbon monoxide partial pressure is greater than about 1 psia (7 kPa) and less than about 500 psia (3446 kPa); and wherein in a hydroformylation process, the hydrogen partial pressure is greater than about 5 psia (35 psia) and less than about 500 psia (3446 kPa).

44. The carbonylation process of Claim 43 wherein the H<sub>2</sub>/CO molar ratio of gaseous hydrogen to carbon monoxide is greater than about 1/10 and less than about 100/1.

45. The carbonylation process of Claim 30, wherein the process is a hydroformylation process, and wherein the process temperature is greater than about 30°C and less than about 120°C.

46. The carbonylation process of Claim 30 wherein the concentration of transition metal is greater than about 10 ppm and less than about 1,000 ppm.